LASER INTERROGATION OF SURFACE AGENTS

BACKGROUND OF THE INVENTION

5   Field of the Invention:

[0001]   The present invention relates generally to determination of the identity of surface agents such as surface-deposited chemicals.

Description of the Background Art:

[0002]   The identification of chemical agents may be conducted under adverse

10   conditions. Such identification may be carried out, e.g. in the field, or at a material entry point. Chemical agents to be identified, may be e.g. hazardous or toxic. Personnel engaged in such identification may wish to be protected from the chemicals by an enclosure. In this way equipment used to perform the identification may be exposed to the substance, while the personnel who operate the equipment are not.

15   [0003]   Raman spectroscopy is one means of identifying unknown chemical agents. Raman spectroscopy equipment, however, is typically designed for static placement in laboratories, and may therefore lack ruggedness and mobility. Raman spectroscopy equipment may not be adapted to relative motion between the equipment and an unknown chemical agent. Such equipment may be large and heavy, and the individual

20   components may not be integrated to the degree required for use in the field.

[0004]   Raman spectroscopy equipment may be placed next to, e.g. a conveyor system carrying objects of various shapes or sizes, on a vehicle, or next to a gate through which objects, such as, e.g. vehicles may be traveling. In cases such as these

there may be relative motion between the Raman spectroscopy equipment and the chemical agent to be analyzed.

[0005]   Ray et al., "Ultraviolet mini-Raman LIDAR for Stand-off, *in situ* Identification of Chemical Surface Contaminants", e.g. describes a related device using the Raman effect. The device is described as portable and rugged enough to be transported in a standard minivan, and capable of operating within minutes of arriving at a scene.

[0006]   Raman spectroscopy equipment used in a laboratory may have a relatively long time window in which to view a sample. A laboratory sample may be analyzed several times to determine of its identity. Raman spectroscopy equipment that is placed next to a conveyor or on a vehicle, on the other hand, may have only a limited period of time in which to analyze a chemical agent. It would thus be desirable for mobile Raman spectroscopy equipment to be able to analyze a chemical agent in a relatively brief period of time, as e.g. a vehicle traverses the ground or a package moves along a conveyor system. It would also be desirable for the identity of a chemical agent to be determinable in a limited number of pulses of, e.g. an output beam.

[0007]   Raman spectroscopy equipment that is mounted on an operational vehicle or alongside a conveyor system may be, e.g. located within in short distance, such as, e.g. two meters, of a chemical agent. It would thus be desirable for Raman spectroscopy equipment to be capable of efficient light collection at that range. Moreover, a distance between the Raman spectroscopy equipment and a chemical agent may vary significantly over time due to, e.g. rugged terrain or a random placement of packages on a conveyor. It would thus be desirable for an optical system to be capable of adjusting its focus to compensate for distance variation.

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[0008] In the event Raman spectroscopy equipment may be used, e.g. in military applications, the equipment may be required to operate for extended periods of time without extensive maintenance. It would be desirable, therefore, for the equipment to be able to function reliably for extended periods of time.

5 **[0009]** Raman spectroscopy equipment may become contaminated by the chemical agents which it analyzes. Raman spectroscopy equipment is normally decontaminated by, e.g. washing it with a chemical, such as, e.g. a chemical solvent. The decontamination process may, however, harm sensitive components comprising the Raman spectroscopy equipment. It would be desirable for Raman spectroscopy

10 equipment to be resistant to contamination from the chemical agents to be analyzed. It would further be desirable for Raman spectroscopy equipment that will be decontaminated to be resistant to chemicals used during the decontamination process. It would further be desirable for Raman spectroscopy equipment that is mounted outside a vehicle or an enclosure to offer no contamination path into the vehicle or

15 enclosure.

[0010] In the event that Raman spectroscopy equipment uses an Excimer laser, the gas inside the Excimer laser may have to be replaced periodically. It would be desirable, therefore, for such a replacement to be relatively quick and easy to perform, so the operation of the equipment is interrupted minimally.

20 **[0011]** Fluorescence of, for example, the surroundings of a chemical agent may interfere with determining an identity of the chemical agent. Soils, in particular, exhibit significant fluorescence when subjected to laser light. It would be desirable, therefore, for the effect of such fluorescence on the analysis of chemical agents to be minimized.

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[0012]   Raman spectroscopy equipment may well be unable to identify a particular chemical agent.   The inability to identify the chemical agent may be due to, e.g. the chemical agent having not been encountered previously, or a malfunction of the equipment. It would be desirable for Raman spectroscopy equipment that comes upon a new or unidentifiable substance to be able to store a signature of the chemical agent for later analysis or troubleshooting. In the meantime, it would be desirable for a list of known chemical agents to be updated to include the new or unidentifiable chemical agent so that a frequency of occurrence of the chemical agent can be determined.

[0013]   There remains a need in the art, therefore, for a transportable Raman spectroscopy device that is capable of analyzing chemical agents moving relative to the device, in the presence of soil fluorescence, without being compromised unduly by decontamination procedures.

SUMMARY OF THE INVENTION

[0014]   The invention provides a relatively compact, lightweight, piece of Raman spectroscopy equipment.

[0015]   In particular, in one aspect the invention provides an apparatus for laser interrogation of surface agents moving relative to the apparatus. A receiver telescope includes a secondary reflector that may compensate for variations in distance from a target to the laser. The secondary reflector relies on a distance to target signal that may be collected at a point substantially away from the target, in the direction of relative motion, to allow a focusing mechanism time to react.

[0016]   In a second aspect the invention provides an apparatus for laser interrogation

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of surface agents moving relative to the apparatus. A receiver telescope includes a secondary reflector that may compensate for variations in distance from a target to the laser. The secondary reflector relies on a distance to target signal that may be collected at a point substantially away from the target, in the direction of relative motion, to allow a focusing mechanism time to react. The laser may emit pulses at a predetermined pulse rate, a variable pulse rate, an operator-controlled pulse rate, or a pulse rate that is proportional to a rate of relative motion of a target relative to the apparatus or a ground rate of relative motion of a vehicle.

[0017] In a third aspect the invention provides a system for laser interrogation of surface agents moving relative to the apparatus. A receiver telescope includes a secondary reflector that may compensate for variations in distance from a target to the laser. The secondary reflector relies on a distance to target signal output by a range finding means that may be collected at a point substantially away from the target, in the direction of relative motion, to allow a focusing mechanism time to react. The focusing means focuses the secondary reflector based on the distance-to-target signal and the rate of relative motion. A spectrograph receives the inelastically scattered radiation from the receiver telescope.

[0018] In a fourth aspect the invention provides a method for laser interrogation of surface agents moving relative to an interrogator in which a receiver telescope compensates for variations in distance from a target to the laser. The secondary reflector relies on a distance to target signal that may be collected at a point substantially away from the target, in the direction of relative motion, to allow a focusing mechanism time to react.

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[0019] A spectrograph receives the inelastically scattered radiation from the receiver telescope, comparing the image of the dispersed spectrum of the target substance to an image of a spectrum of inelastically scattered radiation of a known substance, identifying the target substance if the image of the dispersed spectrum of the target substance matches substantially the image of the inelastically scattered radiation of the known substance, and adding the target substance to a list of unidentified substances if the image of the dispersed spectrum of the target substance does not substantially match any image in database.

[0020] In a fifth aspect the invention provides a system for laser interrogation of surface agents moving relative to the apparatus. A receiver telescope includes a secondary reflector that may compensate for variations in distance from a target to the laser. The secondary reflector relies on a distance to target signal output by a range finding means that may be collected at a point substantially away from the target, in the direction of relative motion, to allow a focusing mechanism time to react. The focusing means focuses the secondary reflector based on the distance-to-target signal and the rate of relative motion. An optical fiber couples inelastically scattered radiation from the secondary reflector to a spectrograph.

[0021] In a sixth aspect the invention provides a system for laser interrogation of surface agents moving relative to the apparatus. A receiver telescope includes a secondary reflector that may compensate for variations in distance from a target to the laser. The secondary reflector relies on a distance to target signal output by a range finding means that may be collected at a point substantially away from the target, in the direction of relative motion, to allow a focusing mechanism time to react. The focusing

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means focuses the secondary reflector based on the distance-to-target signal and the rate of relative motion. An aluminum honeycomb structure carries the components relatively rigidly with respect to one another.

[0022] The above and other features and advantages of the present invention will be further understood from the following description of the preferred embodiments thereof, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. 1 is block diagram of an apparatus for laser interrogation of surface agents moving relative to the apparatus according to one embodiment of the invention;

FIG. 2 is a block diagram of a range-finder according to a second embodiment of the invention;

FIG. 3 is a block diagram of an alternative embodiment of the embodiment shown in Fig. 2;

FIG. 4 shows some geometric parameters;

FIG. 5 shows a time interval;

FIG. 6 shows some vectors;

FIG. 7 shows a method according to a fourth embodiment of the invention;

FIG. 8 shows a second embodiment of the method shown in Fig. 7;

FIG. 9 shows a third embodiment of the method shown in Fig. 7;

FIG. 10 shows a fourth embodiment of the method shown in Fig. 7;

FIG. 11 shows a fifth embodiment of the method shown in Fig. 7; and

FIG. 12 shows a sixth embodiment of the method shown in Fig. 7.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024]   In Fig. 1 is shown an apparatus 100 for laser interrogation of surface agents moving relative to the apparatus 100 according to one embodiment of the invention. Fig. 1 shows a laser 10 outputting an output beam 11, which has, e.g. an axis of transmission 12 and a predetermined wavelength 13. The laser 10 may produce an output beam 11 at a wavelength 13 which, e.g. minimizes soil fluorescence, such as, e.g. a wavelength 13 of less than about 253 nm, such as, e.g. approximately 248 nm.

[0025]   Laser 10 may further include an optical component 49, which could be, e.g. a lens, a filter, or a reflector. In one embodiment, optical component 49 may be held in place with a retaining ring 50.

[0026]   In one alternative embodiment, laser 10 is, e.g. an Excimer laser. If laser 10 is an Excimer laser, the output wavelength 13 of laser 10 may depend on a rare gas-halide with which the resonant cavity is filled. An Excimer laser with a resonant cavity filled with krypton-fluoride (KrF) gas may, e.g. output a wavelength of about 248 nm. Other rare gas-halides that may be used to fill a resonant cavity are, e.g. XeCl, KrCl, ArF, and XeF. In an alternative embodiment, laser 10 is, e.g. a line-narrowed Excimer laser.

[0027]   Laser 10 may also comprise a replaceable gas bottle 43. If laser 10 were to include such a gas bottle 43, the rare gas-halide with which the resonant cavity is filled could be replaced easily by changing out the gas bottle 43.

[0028]   In another alternative embodiment, laser 10 may be, e.g. an Alexandrite laser, a tunable laser in which the resonant cavity is formed of a $BeAl_2O_4$ crystal into which Cr^{+3} ions are embedded. If laser 10 were an Alexandrite laser, a wavelength 13 may

be, e.g. converted to achieve a wavelength 13 of less than approximately 253 nm, for example 248 nm, as would be known to those skilled in the art. In another alternative embodiment, laser 10 may be, e.g. a line-narrowed Alexandrite laser.

[0029] In one embodiment, a beam 11 of laser 10 may be pulsed at a pulse repetition rate (PRR). In one alternative embodiment, the PRR may be made operator selectable. In a more preferred embodiment, the PRR may be variable. In another alternative embodiment, the PRR may depend upon a rate of motion of a target relative to the apparatus 100. A PRR that depends on a rate of relative motion of a target relative to the apparatus 100 may, e.g. allow a probability of detection of a surface agent to be optimized for the prevailing surface contamination distribution characteristics by, e.g. matching the PRR to the rate of relative motion of the target relative to the apparatus 100.

[0030] The Raman spectroscopy system may, e.g. allow for rapid installation and removal of the sensor with minimal impact upon personnel time and vehicle integrity, since it may be self-contained. The Raman spectroscopy system may be, e.g. relatively small and lightweight in order to be easily installed and removed.

[0031] A beam-focusing telescope 14 may have an axis of transmission 12 and may focus substantially the output beam 11. A first reflector 15 also aligned with the axis of transmission 12 then directs the output beam 11 from the beam-focusing telescope 14 in a first direction 16, which may be substantially perpendicular to the axis of transmission 12.

[0032] An output axis 52 of laser 10 may be placed in various other orientations to the same effect by, e.g. adding reflectors, without deviating from the spirit of the invention.

If output axis 52 is, e.g. rotated 90° relative to the position shown in Figs. 1 and 2, a third reflector 53, as shown in Fig. 3, may be interposed between laser 10 and beam-focusing telescope 14 to re-direct the output beam 11 along axis of transmission 12. This might be the case if, e.g. the laser 10 performs or packages better in a particular orientation.

[0033]   An output filter 36 may be, e.g. aligned with axis of transmission 12 or first direction 16, or both, to attenuate wavelengths other than wavelength 13.

[0034]   In the alternative, a reflector coated to transmit predetermined wavelength 13 and reflect other wavelengths may be used, as would be known to those skilled in the art. In this manner undesired radiation, which may degrade the monochromaticity of the emitted output, such as that due to amplified spontaneous emission, can be reduced. An output polarizer 37 may also be, e.g. aligned with axis of transmission 12 or first direction 16, or both, to polarize output beam 11. Such a polarizer 37 may be followed by a filter 42 attenuating unpolarized radiation associated with the output beam, such as amplified spontaneous emission (ASE).

[0035]   A second reflector 17 aligned with the first direction 16 then re-directs the output beam 11 in a second direction 18, which may be substantially perpendicular to the first direction 16. First reflector 15 and second reflector 17 may be placed in various other orientations to the same effect, by appropriately adjusting the orientations of first reflector 15 and second reflector 17, or by adding reflectors, without deviating from the spirit of the invention.

[0036]   A target substance 19 substantially in line with the second direction 18 receives the redirected output beam 11, scattering at least some of it. The scattered

radiation 20 includes elastically, or Rayleigh, scattered radiation 21 which may be at

wavelength 13, and inelastically, or Raman, scattered radiation 22 which occurs at a

spectrum of wavelengths 23 which are characteristic of the target substance 19.

[0037]   A receiver telescope 24, preferably of the Cassegrain variety, having a focal

direction 39 substantially opposite to said second direction 18 may be arranged to

collect at least some of the inelastically scattered radiation 22. The receiver telescope

24 may be composed of a primary or receiver reflector 25 for collecting the inelastically

scattered radiation 22, and a secondary or focusing reflector 26 for focusing the

inelastically scattered radiation 22.

[0038]   In one embodiment, primary reflector 25 may be disposed to reflect at least

some radiation 22 scattered inelastically from target 19 toward secondary reflector 26.

The surfaces of primary reflector 25 and secondary reflector 26 may be profiled to focus

inelastically scattered radiation 22 at a first focal point 46, which may not be a focal

point of either primary reflector 25 or secondary reflector 26 individually.   First focal

point 46 instead results from the combined effects of the surfaces of primary reflector 25

and secondary reflector 26 on the path of inelastically scattered radiation 22.

[0039]   The location of first focal point 46 depends, in general, on the relative degrees

of curvature of primary reflector 25 and secondary reflector 26. If, e.g. primary reflector

25 has a relatively greater degree of curvature than secondary reflector 26, rays of

inelastically scattered radiation 22 that reflect from primary reflector 25 to secondary

reflector 26 may converge substantially at first focal point 46.

[0040]   Secondary reflector 26 may have a focusing mechanism 27, such as, e.g. a

voice coil actuator, an electric motor, a piezoelectric actuator, a linear motor, a

pneumatic actuator, or a hydraulic actuator to move secondary reflector 26 along focal

direction 39 until inelastically scattered radiation 22 is focused at first focal point 46.

[0041]   In one embodiment, either of the primary reflector 25 or secondary reflector 26

may be made to transmit substantially radiation of the polarization of the output beam

11, rather than reflecting it. In another embodiment, light of the polarization of the

output beam 11 may be blocked by a lens 38 associated with, e.g. receiver telescope

24. Such a lens 38 may be, e.g. aligned substantially with said focal direction 39.

[0042]   In one embodiment, any of the first reflector 15, second reflector 17, primary

reflector 25, and/or secondary reflector 26 may be made to transmit substantially visible

light, rather than reflecting it. Thus the visible component of sunlight may pass through

the reflectors instead of being collected into receiver telescope 24.

[0043]   In the preferred embodiment, the apparatus 100 may be designed to be

resistant to a decontamination process, i.e.: the apparatus 100 may be subjected to

high-pressure corrosive liquid chemical cleaning without adversely effecting the

operating performance of the unit.   This may be accomplished by, e.g. sealing joints in

apparatus 100, with, e.g. O-rings or polymers.

[0044]   A portion of the Raman spectroscopy system may be, e.g. mounted outside a

vehicle or an enclosure. That portion that is mounted outside the vehicle or enclosure

may be, e.g. self-contained and sealed so as to resist contamination by the vehicle

environment. In the event the Raman spectroscopy system becomes contaminated it

may be decontaminated with the usual chemicals and cleaning procedures.

[0045]   That portion that is mounted outside the vehicle or enclosure may be sealed

by, e.g. incorporating "O" rings in all joints, applying a layer of a blown tar or a soft

polymer to the external surfaces of the joints, or taping threaded joints with PTFE tape.

[0046] If a portion of the Raman spectroscopy system is mounted outside the vehicle or enclosure, individual components of the Raman spectroscopy system may be divided between the interior and the exterior of the vehicle. In one alternative, the laser 11, receiver telescope 24 and spectrograph 33, e.g. may be placed inside the vehicle or enclosure, with reflectors outside the vehicle or enclosure to guide the outgoing beam and the incoming elastically scattered radiation to or from them. In another alternative, the laser could also be placed outside the vehicle or enclosure. In a third alternative, the spectrograph 33 could also be placed outside the vehicle or enclosure. Other alternatives would be apparent to those skilled in the art.

[0047] Signals to be sent from the components of the Raman spectroscopy system placed outside the vehicle or enclosure may be, e.g. transmitted electrically or optically to those inside the vehicle to decouple a chemical or biological transmission path.

[0048] Signals could be, e.g. converted from electrical to optical, or vice versa, to facilitate their transmission among the various components of the system. Filters or reflectors that have to be placed in the beam path in any case may, e.g. double as ports between the inside and the outside of the vehicle. Waste heat from the laser and other components internal to the Raman spectroscopy system may be exhausted directly to the exterior without compromising decontamination compatibility.

[0049] In one embodiment, apparatus 100 includes a structure 40 made of, e.g. an aluminum honeycomb covered by carbon epoxy. Other strong, lightweight materials would be known to those skilled in the art. In a further embodiment, laser 10, beam-focusing telescope 14, receiver telescope 24, first reflector 15, second reflector 17,

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primary reflector 25, secondary reflector 26 spectrograph 33, and/or range-finder 29

may be mounted on structure 40.   In a preferred embodiment, laser 10, beam-focusing

telescope 14, receiver telescope 24, first reflector 15, second reflector 17, primary

reflector 25, secondary reflector 26, spectrograph 33, and/or range-finder 29 may be

5   mounted on structure 40 using fasteners 41, such as, e.g. a screw, a bolt, a rivet, or a

pin.

[0050]   In one embodiment, structure 40, laser 10, beam-focusing telescope 14,

receiver telescope 24, first reflector 15, second reflector 17, primary reflector 25,

secondary reflector 26, and/or range-finder 29 may be made of materials having

10   substantially similar coefficients of thermal expansion, such as a predetermined

coefficient of thermal expansion. In a preferred embodiment, predetermined coefficient

of thermal expansion is a relatively low coefficient of thermal expansion, such as 1.00

$\times 10^{-5}$.

[0051]   In another embodiment, shown in Fig. 1, filters 30 or light baffles 31, or both,

15   may be placed between the target substance 19 and the receiver reflector 25 to

attenuate radiation at wavelength 13 from among scattered radiation 20, thus blocking

elastically scattered radiation 21. Filters 30 or light baffles 31 may also be placed at

other points in and around the path of inelastically scattered radiation 22, such as, e.g.

along focal direction 39 to the same effect, as would be known to persons skilled in the

20   art. For example, these elements may be placed at the output of the telescope located

near the hole in the primary mirror 25. In one embodiment, filter 30 is integral with

receiver telescope 24. In a preferred embodiment, filter 30 is integral with primary

reflector 25.

[0052] Filter 30 may be, for example, a line or a bandstop filter whose stop band coincides with wavelength 13, or a long-pass edge filter whose pass band may be tuned to wavelengths longer than wavelength 13. Filter 30 may also be composed of a succession of short- and long-pass edge filters and reflectors that amount to a line filter or a bandstop filter, as would be known to persons skilled in the art. In this way at least some of elastically scattered radiation 21 is not processed further.

[0053] Inelastically scattered radiation 22 may be coupled from secondary reflector 26 to spectrograph 33. In one embodiment, inelastically scattered radiation 22 may be coupled from secondary reflector 26 to spectrograph 33 using an optical fiber coupling 32 having a first end 44 and a second end 45. In the alternative, optical fiber coupling 32 may be, e.g. several optical fibers, such as a bundle of optical fibers.

[0054] Spectrograph 33 includes a focal plane array (FPA) detector 34 that may be, for example, a charge coupled device (CCD). In an alternative embodiment, focal plane array detector 34 may be an intensified charge coupled device (iCCD). Spectrograph 33 further includes a diffractor 35 that may be, for example, a diffraction grating, such as a Bragg grating, or a prism, for distributing the spectrum of constituent wavelengths of inelastically scattered radiation 22 across a plane of focal plane array detector 34. The constituent wavelengths are then converted into a computer-readable signal by the focal plane array detector 34.

[0055] In an alternative embodiment, shown in Fig. 2, reflector-focusing mechanism 27, i.e. an auto-focus, focuses secondary reflector 26 using a distance-to-target 28 signal from range-finder 29, which may be, e.g. a laser range-finder, along with a rate of relative motion 204. Secondary reflector 26 may be focused by, e.g. adjusting a

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position of secondary reflector 26 with an actuator such as, e.g. a voice coil actuator, an electric motor, a piezoelectric actuator, a linear motor, a pneumatic actuator, or a hydraulic actuator.

[0056] In one embodiment, rate of relative motion 204 may default to a predetermined constant. This would be the case if, e.g. rate of relative motion 204 were unavailable.

[0057] Distance-to-target 28, as the name implies, is a distance from a known point 201 within the apparatus 200, such as, e.g. the point shown in Fig. 2, to some point 202 from which the range to target substance 19 may be estimated. Such a known point 201 is preferably stationary relative to receiver reflector 25 and could be, for example, at the output of range-finder 29.

[0058] A velocity 203 of the target substance 19 relative to the apparatus 200 comprises a rate of relative motion 204 in a direction 205. Range-finder 29 outputs distance-to-target 28 signal in a third direction 206. Third direction 206 is at a forward look angle, e.g. a pre-determined non-zero angle 51, to second direction 18 in direction 205 of relative motion 204.

[0059] In one embodiment, range-finder 29 may look ahead of the target 19 as target 19 moves relative to the apparatus 200. A signal output by range-finder 29 would thus be available to predict or estimate the distance to target 19 before target 19 is at the sensing location. Telescope focus may thus be maintained, given the limiting rate of relative motion or response time of the secondary reflector 26, for any target 19 rate of relative motion and terrain condition, within the telescope's mechanical range limits.

[0060] Telescope focus may be maintained by measuring distance-to-target 28 away from target 19, in the direction of relative motion 204. In this way a focusing mechanism

27 of secondary reflector 26 may be given sufficient time to respond to a change of distance-to-target 28 and achieve proper focus for the next laser pulse. The distance ahead for which distance-to-target 28 is measured is a function of the reaction time of the focusing mechanism 27 of secondary reflector 26, focus range increment, absolute range, rate of relative motion 204, and rate of change of relative motion.

[0061] Pre-determined non-zero angle 51, i.e. the forward look angle FLA, may be a function of several variables, such as, e.g. a relative velocity of a target. Forward look angle FLA may be, e.g. adaptive, or fixed. If forward look angle FLA is fixed, on the other hand, an algorithm may be used to process e.g. the target relative velocity data to allow the angle to be adjusted for analysis conditions. Since making forward look angle FLA variable would entail an increase in mechanical complexity, a fixed forward look angle FLA is a preferred approach.

[0062] Secondary reflector 26 may be adjusted by, e.g. measuring the look-ahead (slant) range at a relatively high repetition rate with range finder 29, selecting a particular range finder data sample (RFRN) , and converting it to an estimate of distance-to-target 28. Distance-to-target 28 may then be used to adjust a focus of secondary reflector 26. Secondary reflector 26 may be focused based on several parameters. These factors, as shown in Figs. 4, 5, and 6, may include, e.g. forward look angle FLA which may be a predetermined non-zero angle of the range-finder direction to the direction in which the target is viewed, ground distance covered between laser shots GDC, look ahead distance between laser & range finder spot LAD, range finder pulse rep rate in Hz RFPRR, range finder range RFR, site-line offset of range

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finder aperture from FR vector SLO, vehicle acceleration VA, vehicle speed VS, time between laser pulse and range finder RFR sample data TLR.

[0063] A particular range finder 29 data sample that represents, e.g. the range to the next target 19 is referred to as the range finder number RFRN. Range finder number RFRN may be identified with the following equation:

$$RFRN = ROUND[((GDC - LAD) / RFGD) + SOC] \qquad (eq\ 41\text{-}1)$$

Where;

$$LAD = SLO + RFR * SIN\ FLA \qquad (eq\ 41\text{-}2)$$

$$GDC = VS * TLP + 0.5 * VA * TLP2 \qquad (eq\ 41\text{-}3)$$

$$RFGD = VS * TRP + 0.5 * VA * TRP2 \qquad (eq\ 41\text{-}4)$$

$$VA = (VSn - VSn\text{-}k)/k*TLP \qquad (eq\ 41\text{-}5)$$

where K = 1, 2, 3 . . . ., the sample interval

$$SOC = RFSD + (1 - (TLR * RFPRR))$$

[0064] The terms of equations 41-1 through 41-5 may be defined as follows:

FLA   Forward Look Angle of Range Finder

GDC   Ground Distance Covered Between Laser Shots

LAD   Look Ahead Distance Between Laser & Range Finder Spot

RFPRR   Range Finder Pulse Rep Rate - Hz

RFGD   Range Finder Ground distance

RFR   Range Finder Range

RFSD   Range Finder Sample Delay

RFRN   Range Finder Number (RFR selection)

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SLO   Site-line offset of range finder aperture from FR vector -- measured

parallel to VS vector

SOC   Sample Offset Correction (adjusts calculated RFR sample tag number for

time offset between laser pulse and range finder pulse)

5   TLP   Time to next Laser Pulse - ms

TLR   Time between Laser pulse and Range finder RFR sample data

TRP   Time between Range finder Pulses

VA   Vehicle Acceleration

VS   Vehicle Speed

10   **[0065]**   RFRN may be selected based on several subsystem parameters and results in

a correct telescope focus in the presence of varying external system parameters of

vehicle acceleration and velocity and changing ground slope.

[0066]   In one embodiment, shown in Fig. 1, optical fiber 32 may be a circular-to-line

optical fiber bundle whose output geometry matches the geometry of focal plane array

15   detector 34, for maximal coupling with highest spectral resolution of inelastically

scattered radiation 22 to focal plane array detector 34. Additional coupling optics may

be required to efficiently couple the light from secondary reflector 26 to optical fiber 32.

These optics may also include the optical filter to remove elastically scattered radiation

at wavelength 13.

20   **[0067]**   In another embodiment, first end 44 of optical fiber 32 may be substantially

coincident with first focal point 46. First end 44 may be, e.g. a convex surface to allow

secondary reflector 26 to have some range of motion while still coupling inelastically

scattered radiation 22 efficiently. Second end 45 may be centered in diffractor 35. In a further embodiment, second end 45 may be integral to diffractor 35.

[0068] Spectrograph 33 may further include a parabolic reflector 47 to receive inelastically scattered radiation 22 dispersed from second end 45. Second end 45 may be coincident with a focal point 48 of parabolic reflector 47. Parabolic reflector 47 will thus collimate dispersed inelastically scattered radiation 22 towards diffractor 35.

[0069] In an alternate embodiment, the spectrograph 33 may be located at a distance from the sensor, possibly housed with an analysis computer internal to the vehicle. In this case, an additional optical fiber may be used to couple the light from the optics at the rear of the telescope to the spectrograph. In an alternative embodiment, the spectrograph and related equipment may be coupled to the receiver telescope with, e.g. an infrared, electronic, or inductive link, in order to decouple a chemical or biological contamination path into the vehicle.

[0070] Finally, the signal from focal plane array detector 34 may be coupled to appropriate software for comparing the detected spectral array to a library of spectral arrays of known chemical agents until a match is found, or the signal is determined to be an unknown or new chemical agent. If, e.g. the signal is undetermined, it may be added to the database so that statistics can be collected for further analysis.

[0071] In a fourth embodiment, as shown in Fig. 7, the invention comprises a method for laser interrogation of surface agents moving relative to an interrogator including the steps of providing a laser, outputting a substantially monochromatic beam from the laser, focusing the beam with a beam-focusing telescope, directing the beam at a target substance, measuring a relative motion between beam and target substance, receiving

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a distance-to-target signal for a point offset substantially from target substance,

adjusting a focus of a receiver telescope based on relative motion and distance-to-target signal, receiving inelastically scattered radiation from the target substance at a

spectrum of wavelengths characteristic of the target substance with the receiver

5   telescope, dispersing the spectrum of wavelengths of the inelastically scattered

radiation, imaging the dispersed spectrum onto a focal plane array detector, comparing

the image of the dispersed spectrum of the target substance to an image of a spectrum

of inelastically scattered radiation of a known substance, identifying the target

substance if the image of the dispersed spectrum of the target substance matches

10   substantially the image of the inelastically scattered radiation of the known substance,

and adding the target substance to a list of unidentified substances if the image of the

dispersed spectrum of the target substance does not substantially match any image in

database.

[0072]   As shown in Fig. 8, the step of providing a laser in the method for laser

15   interrogation of surface agents may comprise further the steps of disengaging an on-

board cylinder, releasing an on-board cylinder retainer, removing on-board cylinder, and

installing a new on-board cylinder. As shown in Fig. 9, the step of disengaging an on-

board cylinder may be preceded by the steps of indicating a low gas bottle pressure and

locking on-board valves shut. As shown in Fig. 10, the step of installing a new on-board

20   cylinder may be followed by the steps of purging gas lines by releasing gas from on-

board cylinder, venting gas through on-board cylinder gas filter, and replenishing a gas

in a laser. As shown in Fig. 11, the step of outputting a substantially monochromatic

beam from the laser in the method for laser interrogation of surface agents further includes setting a pulse rate of the laser.

[0073] As shown in Fig. 12, the step of adjusting a focus of a receiver telescope may comprise further the steps of receiving a range-to-target data sample, tagging the range-to-target data sample with a time sequence, receiving a relative motion data sample, calculating a rate of change of the relative motion, correcting the range-to-target data sample for the relative motion, correcting the range-to-target data sample for rate of change of the relative motion, correcting the range-to-target data sample for a laser pulse rate, correcting the range-to-target data sample for a range-finder pulse rate, correcting the range-to-target data sample for range-finder position relative to a receiver telescope line-of-sight, correcting the tagged range-to-target data sample for a waveform de-synchronization time offset, transforming a set of co-ordinates of corrected tagged range-finder sample to a receiver telescope line-of-sight, and converting range-to-target sample to an equivalent receiver telescope secondary reflector position.

[0074] In an alternative embodiment the step of identifying the target substance in the method for laser interrogation of surface agents is carried out in substantially real time.

[0075] While the invention has been described in detail above, the invention is not intended to be limited to the specific embodiments as described. It is evident that those skilled in the art may now make numerous uses and modifications of and departures from the specific embodiments described herein without departing from the inventive concepts.